AN INVESTIGATION ON THE INFLUENCE OF SOUNDSCAPES AND FOOTSTEP SOUNDS IN AFFECTING PREFERRED WALKING PACE

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ABSTRACT

In this paper we describe an experiment whose goal is to investigate the role of footstep sounds and soundscapes to affect the pace of a person who is walking in place, e.g., mimicking the act of walking without leaving the current position. The results of a preliminary experiment with nine subjects show that people change their walking pace when exposed to different soundscapes.

1. INTRODUCTION

In recent years, research on the role of auditory feedback in walking has received an increased attention. For example, it has been shown that following a rhythmic cue helps gait performance in patients with Parkinson's disease [2] or strokes [10]. In non-clinical cases, research shows that humans are able to synchronise to music in a broad range of tempi [9]. Moreover, recent studies show that recurrent patterns of fluctuation affecting the binary meter strength of the music may entrain the vigour of walking movement [5]. Interactive sonification of footstep sounds has also shown to manipulate pace of participants independently from their intended emotional expression [1].

In previous research, we explored walking as a rhythmic action and experimentally investigated the effect of auditory feedback [7] in a closed-loop interactive sonification framework [4]. Different kinds of auditory feedback were compared, including ecological feedback such as footsteps on wood and gravel as well as a non-ecological feedback such as a sinetone. Moreover, three kinds of rhythmic interactions were compared, specifically footsteps played at a constant tempo, footsteps generated interactively by the user and footsteps that adapted to the user. Results showed that feedback with ecological sounds resulted in a performance comparable to sine waves, and, in the case of wood, provided a more stable tempo. In this paper we are interested in further exploring this topic, investigating whether the addition of soundscapes affect the preferred pace of a person. In previous research, it was shown that soundscapes enhance the recognition of the sound of simulated footsteps [8]. According to our hypothesis, a soundscape creates a sense of place and affects the pace: people walking at the beach tend to walk slower than people walking in a busy city environment. In order to test this hypothesis, we designed an experiment described in the following section.

2. EXPERIMENT DESIGN

We designed an experiment to further explore the influence of footstep sounds and additional soundscape on preferred pace of a person. We tested four auditory feedback conditions (gravel, wood, sine wave, silent) with four different soundscapes (cafe, busy office, sea shore and street) all in randomised order. Our previous research [7] showed that different types of auditory feedback, which we hear while walking can influence our preferred walking pace. There are several possible explanations for this phenomena [11]. We wanted to explore one of them, which states that people change the preferred walking pace due to the associated meaning of feedback and memories of actions performed with the same feedback in real life.

In this experiment, we used soundscapes to emphasise and reinforce the meaning enclosed in the auditory feedback. We chose soundscapes which can be associated with gravel or wood, but not with both of them at the same time. A coffee place and a busy office soundscape can be combined with wood footsteps feedback. A sea shore and a street can be combined with gravel feedback. Each pair of soundscapes includes one which in our opinion could induce fast, and a second one which induces slow pace of walking. Table 1 summarises the experiment design. In each of the 20 trials participants were asked to walk in their own preferred pace. After each trial participant were asked several questions which are specified in the list below.

Q 1 Evaluate the sense of effort you experienced while

SECTION	SOUNDSCAPE	FEEDBACK	QUANTITY
A1	seashore, busy street, cafe, busy office	gravel, wood, sine wave	12
A2	seashore, busy street, cafe, busy office	none	4
B	none	gravel, wood, sine wave	3
C	none	none	1

Table 1: Summary of the experiment design. The experiment was divided into four sections with respective number of trials from a column QUANTITY. The number of trials was dictated by a combination of all soundscapes and footstep sounds used in each section.

Figure 1: A visualization of the setup used in the experiment.

walking (1 no effort - 7 high effort).

Q 2 It was easy to walk while listening to the sounds of footsteps and soundscapes (1 very easy - 7 very hard).

Q 3 The pace I kept while walking was: (1 very slow - 7 very fast).

Q 4 Feedback felt as a natural consequence of walking. Consider only footsteps sounds (1 strongly disagree - 7 strongly agree).

Q 5 Feedback felt as a natural consequence of walking. Consider footsteps sounds and soundscape (1 strongly disagree - 7 strongly agree).

Q 6 Feedback was congruent with soundscape (1 strongly disagree - 7 strongly agree).

Q 7 In which place do you think you were walking?/On which surface do you think you were walking?

3. SYSTEM ARCHITECTURE

For the purpose of the experiment we built a simple setup shown in Figure 1. The participants were asked to walk in their own pace on the aerobic stepper. A microphone (Shure beta 91) was placed below and connected to a sound card (Fireface 800). A Max/MSP patch was responsible for step detection and presentation of auditory feedback according to the participants' footsteps in real time. Both soundscape and auditory feedback were played through headphones (Panasonic RPHTX7). The choice of headphones was motivated by the fact that the auditory feedback could be used as feedback for walking or running outdoors. In-depth explanation of the detection and synthesis engine is reported in [7, 6]. The feedback sounds of footsteps were generated online and matched participants' steps. Soundscapes were static and presented from audio files.

4. RESULTS

Nine subjects (2 female and 7 male) participated to our experiment; their average age was 27.9 ($s = 4.5$). The small sample of participants was dictated by a exploratory character of the experiment. Since the results are very promising in our opinion, the experiment will be extended in the near future. Our analysis of experimental data was based on information about each participant's preferred walking pace measured in BPM (the tempo was recorded every time the system detected one step). The analysis was conducted based on the average tempi and reported results from the questionnaires.

We used four statistical tests in our analysis: one-way repeated-measures ANOVA, factorial repeated-measures ANOVA for metric values, Friedman' s ANOVA, the Wilcoxon signed-rank test and Kendall's tau correlation for ordinal data from questionnaires [3]. The use of the listed tests was dictated by the types of data that we obtained in the experiment, the amount of factors, and the within-subjects experiment design. Kendall's tau correlation was used specifically because of small sample size and the type of data acquired with questionnaires (ordinal).

4.1. Soundscape

In line with our hypothesis, participants changed their preferred pace according to the type of soundscape. It is worth to mention that participants were only asked to walk in their preferred pace. They were not instructed explicitly to match the 'mood' of soundscape with their pace. Even though, the effect of a difference between soundscapes on the average pace was significant ($F(4, 32) = 6.69, p < 0.001$) (see Figure 2). As we expected, participants had the slowest

pace with a sea shore soundscape. The cafe soundscape was also distinctly slower than the three others. The busy street and office caused faster preferred tempo. Trials without any soundscape revealed that participants tempo was similar to the ones assigned by researchers as 'fast'.

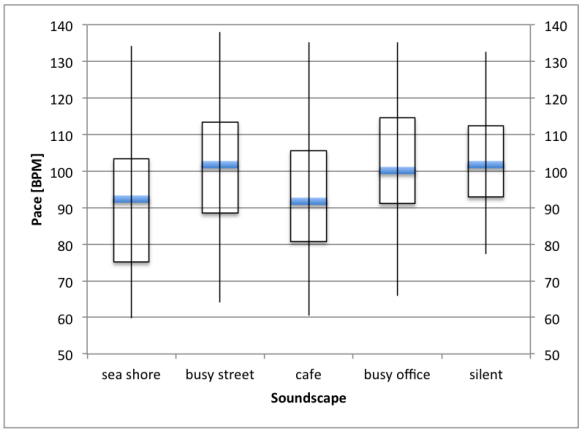

Figure 2: A visualisation of the experiment results for the soundscape variable.

4.2. Footstep Sounds

The analysis also revealed significant differences within footsteps variable ($F(3, 24) = 3.264, p < 0.05$) (see Figure 3). As it was shown in a few of our previous experiments [7, 6] participants walk in the slowest tempo with gravel as a feedback, followed by wood and then sine wave.

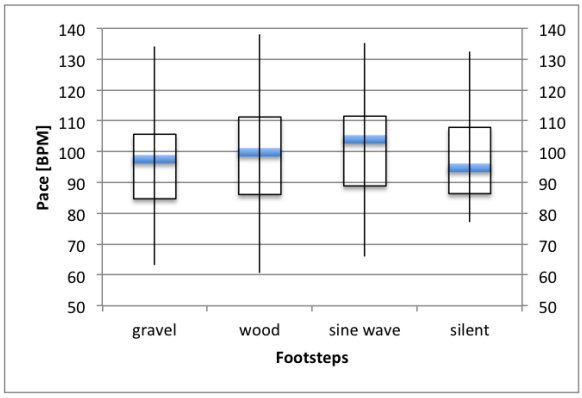

Figure 3: A visualisation of the experiment results for the footsteps variable.

QUESTIONS	p	CORRELATION
Q3 vs Q4	< 0.05	-0.178
Q3 vs Q5	$= 0.001$	-0.263
Q3 vs Q5	< 0.05	-0.173
Q4 vs Q5	< 0.001	0.446
Q4 vs Q6	< 0.001	0.364
Q5 vs Q6	< 0.001	0.746

Table 2: Summary of the significant correlation between specified sets of data (Kendall's tau).

4.3. Mixed effect

One-way repeated-measures ANOVA within footsteps variable category showed that soundscape significantly influenced the average pace, but analysis within soundscape variable category showed that footsteps did not significantly changed average pace (see Figure 4). This means that the soundscape strongly affected the average pace and overtook the footsteps variable.

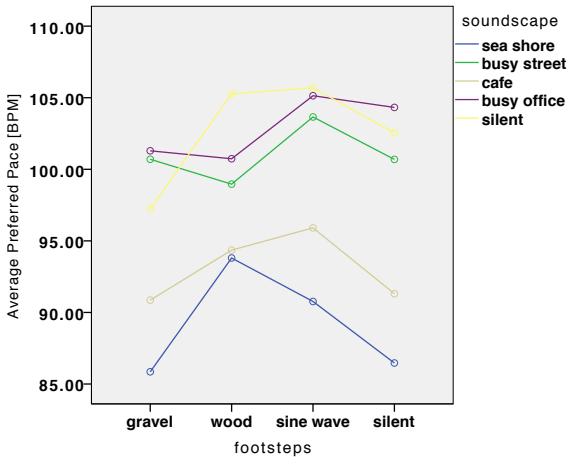

Figure 4: A visualisation of the experiment results for the mixed soundscape*footsteps effect.

4.4. Questionnaires

We focused on the correlation in answers between questions. Kendall's tau test showed significant correlation between several sets of data, which is summarised in table 2.

5. DISCUSSION

With this work we aimed to show the influence of different types of soundscape and footsteps sounds on preferred pace

FEEDBACK	p	Chi-square
gravel	< 0.001	23.86
wood	> 0.05	3.76
sine wave	> 0.05	3.58

Table 3: Summary of the results from Friedman ANOVA for the question number six for trials 1-12.

of the participants. Even though we tested only 9 participants, the interesting results were acquired. It motivates to continue this work and look in-depth into the preferences and causes for choice of preferred pace while walking. We can conclude that tested variables have an effect on preferred pace. The strong influence of soundscape suggests that meaning and memories conveyed by this stimulus can easily affect the pace. It suggest that the same factor, at least partially explains changes in preferred pace caused by footsteps sounds. Since much more information is included in soundscape sounds than in footsteps presented separately, the effect of soundscape is much stronger and might overtake the influence of footsteps variability.

To test the mixed effect we used soundscape, which are congruent and incongruent with chosen sounds of footsteps. Since, perceived by participants variation of perceived congruency between soundscapes and footsteps sounds was much higher than the expected one we can not definitely conclude on the mixed effect. Further studies, with higher amount of participants should lead us to more precise results. Based on the Figure 4 we can expect to prove with significance that e.g. wood, which is one of the type of tested footsteps sounds makes participant walk faster than with gravel, but only when its combined with 'slow' soundscape. On the other hand gravel and wood are not different when combined with 'fast' soundscape. Sine wave, as an unnatural feedback, which can not be find in real life, makes people walk faster in comparison to the rest of footsteps sounds which are combined with soundscapes and without soundscape. We believe that because sine wave does not convey any information, which might be associated with real life event its not influenced by the effect of soundscape.

In-depth analysis of the differences between soundscape within each category of feedback shows significant differences for all types of feedbacks excluding the wood. We think that this effect might be caused by perceived congruency between soundscapes and sounds of footsteps. Participants perceived wood as more or less congruent with all of the soundscapes. Even though we can see that there is a difference between average pace within wood category is not that big, as it this in case of gravel or sine wave. We believe that the reason is mixed effect of congruency on a level of combining soundscape and footsteps, but also the general meaning and associated speed with soundscapes by itself.

6. CONCLUSION

The goal of presented study was the investigation of the cause of the change of preferred pace while different sounds of footsteps are played as a feedback. We have been exploring the idea of the meaning conveyed by footstep sounds and associations of places induced by these sounds. To test our hypothesis, we adopted previously sonified footsteps (gravel, wood, and sine wave), and proposed soundscapes which are congruent with them in a matter of possible coexistence in every day life. Moreover, we chose both 'fast' and 'slow' soundscapes.

With a statistical analysis, we partially confirmed our hypothesis. Moreover, also the non statistically significant results showed patterns, which might be demonstrated when redoing the tests using a larger sample set. The experiment showed that different types of soundscapes and footstep sounds can influence the preferred walking pace. Our results have several applications. For example, in the field of music and movement, where for example the pace of runners can be increased or decreased by changing the auditory feedback.

7. REFERENCES

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